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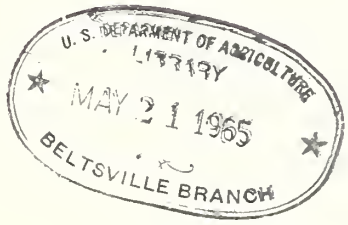
Marketing Research Report No. 605

Experimental Effects of Sodium Polyphosphates on WEIGHT OF FRYER CHICKENS During Chilling



UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

PREFACE

This study is part of a broad program of research by the Market Quality Research Division of the Agricultural Marketing Service on technical problems in the marketing of poultry. The research was carried on in a commercial plant in cooperation with industry in 1961 and 1962.

Townsends, Inc., Millsboro, Del., supplied facilities, and the Calgon Company, Pittsburgh, Pa., supplied the phosphate mixture.

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EXPERIMENTAL EFFECTS OF SODIUM POLYPHOSPHATES ON WEIGHT OF FRYER CHICKENS DURING CHILLING

by

James E. Thomson, Anthony W. Kotula, and James F. Novotny
Field Crops and Animal Products Branch
Market Quality Research Division
Agricultural Marketing Service

SUMMARY

Moisture uptake by fryer chickens during chilling and moisture losses during holding and shipping were investigated. The influence of added phosphates, duration of chilling, method of chilling, added sodium chloride (NaCl), initial pH, duration of air agitation of the chilling medium, and temperature of chilling medium on mean percent gains in weight were studied.

Fryers chilled for 6 hours in water containing 8 ounces of phosphate mixture per gallon gained less weight, as percent of dry eviscerated weight, than birds chilled in water without phosphate. However, when weighed after 24 hours, both of these groups showed about the same gain, because the loss of moisture, or "weep," in the phosphate-treated birds was less.

If continuous chilling preceded any of the 6-hour-chill treatments (plain water, phosphate, NaCl), the moisture absorbed by the fryers usually exceeded the percentage permitted by regulations of the U. S. Department of Agriculture.

Birds chilled in only a 6-hour treatment showed a relatively low (4 to 4.5 percent) gain, whereas those chilled by a combination of continuous and 6-hour treatment chilling showed a relatively high (11 to 12.5 percent) gain. During the first 24 hours of shipping and holding, however, the low- and high-gain groups of birds lost about the same proportion of the total weight gained during chilling (about 1/4 for phosphate-treated birds, and about 1/3 for birds not treated in phosphate). Between 24 and 72 hours of holding, the low-gain birds either lost very little or gained weight, whereas the high-gain birds lost a greater proportion of their gained weight than the low-gain birds. This loss in the high-gain birds amounted to about 1/20 for phosphate-treated, and about 1/10 for non-phosphate-treated birds.

Birds chilled in water containing 0.112 and 1.120 ounces of NaCl per gallon gained about the same weight as birds chilled in plain water.

Birds chilled at pH 10 showed a significantly higher percentage gain than birds chilled at pH 3, 5, 7, 8, or 9. Moisture uptake tended to decline between pH 3 and pH 5 and to increase between pH 5 and pH 10.

Within the limits of this study, no significant differences were found among gains as influenced either by time of air agitation or temperature of the chilling media.

BACKGROUND

Salts of weak acids, such as polyphosphates, have been used extensively in the commercial processing of meats, particularly cured meats such as hams. The use of phosphates in such products is primarily intended to improve color stability (4)[1], and to decrease cooking and processing losses (1). The commercial use of polyphosphates in

[1] Underscored figures in parentheses refer to items in "Literature Cited, "p. 10.

poultry processing has been proposed, and claimed benefits include improved flavor and tenderness, reduced cooking time, longer shelf-life due to inhibition of oxidative rancidity, and reduced loss of moisture ("weep") from the carcass during shipping and holding (8).

PURPOSE

The extent to which chicken carcasses take up and retain moisture during processing, shipping, and holding is of great importance to processors, regulatory agencies, and consumers. It is related to yield and to the problem of adulteration. Many factors affect moisture uptake and retention. The purpose of this study was to determine the effect of some of these factors, particularly the use of polyphosphates in the chilling medium. These factors included (1) proportion of added phosphate mixture; (2) total chilling time; (3) proportion of added sodium chloride; (4) initial pH; (5) period of air agitation of chilling medium; (6) temperature; and (7) continuous in-line chilling coupled with subsequent treatment chilling.

PROCEDURE

The studies consisted of four trials carried out in a commercial broiler-fryer processing plant in the Delmarva area.

Common to All Trials

Production rate of the plant at which samples were taken was about 5,000 chickens per hour. Chickens were scalded at 129° F. and picked in free-style, batch-type pickers. The chickens used in the tests were removed from the processing line at a point after evisceration but before the final washer. This point was selected to eliminate the effect of final washing on the moisture content of the chickens. Care was exercised to exclude from the samples all birds from which parts or skin had been removed in excess of the normal at that stage of processing. For example, birds with limbs removed or with blisters or part of breast skin stripped away were excluded. All birds selected had been processed in a manner to conform to U. S. Department of Agriculture regulations (15) concerning methods used to make eviscerating cuts (openings in thigh and neck areas). Each bird was tagged with a numbered plastic legband to identify it throughout the experiment, and was weighed to the nearest 0.01 pound.

For the treatments, the birds were distributed into 20-gallon polyethylene containers according to a schedule of random numbers. The chilling solution was added to the containers at the rate of 1/2 gallon per bird. To maintain chilling temperatures, crushed ice in watertight plastic bags was placed in the containers. Plastic bags were used to insure that the volume of chilling solution and the concentration of the added compounds did not change during the chilling period. This procedure also eliminated the effect of proportion of ice to water on uptake cited by Mickelberry and others (10).

After chilling, the birds were removed from the containers, and hung by the hocks on draining racks for 20 minutes. After being drained and weighed, the birds of each treatment were icepacked, separately from other treatment lots, in wirebound crates for shipping. The birds were shipped about 150 miles and held in the crates at 40° F. After the holding periods, the birds were taken from the icepack and, after adhering ice was removed, weighed.

"Percentage gain" for each bird was the difference between its weight when removed from the line (dry eviscerated weight) and its weight after chilling or holding, divided by the dry eviscerated weight and multiplied by 100.

The phosphate was a commercial mixture of food-grade sodium polyphosphates. The phosphate manufacturer recommends the use of 8 ounces per gallon of chilling medium (6%), and a treatment period of 6 to 24 hours.

All data were subjected to electronic data-processing procedures, and analyses of variance and Duncan's Multiple Range Test (2) were applied.

The Four Trials

Trial I

The treatments for Trial I were:

(a) chilling time (2, 6, 18, or 24 hours) and
(b) proportion of phosphate mixture (none or 8 ounces per gallon).

There were 12 birds per treatment per replicate, 4 replicates (2 a day for 2 days), for a total of 384 birds. Each bird was weighed three times--when removed from the line, at the end of the chilling period, and 24 hours after chilling.

Trial II

The treatments for Trial II were:

(a) method of chilling (with or without continuous chilling) and
(b) proportion of phosphate mixture (none, 4, or 8 ounces per gallon)
or
proportion of NaCl (none, 0.112, or 1.120 ounces per gallon).

The counterflow tumble-type continuous chiller was used (7). Regulations of the U.S. Department of Agriculture allow 0.112 ounces of NaCl per gallon with no statement on the label, and 1.120 ounces per gallon providing it is so declared on the label of the product (16). The birds were chilled for 6 hours. There were 8 birds per treatment per replicate, 4 replicates (2 a day for 2 days), for a total of 320 birds.

Birds receiving the treatment that included continuous chilling were weighed five times--when removed from the line, after continuous chilling, at the end of the 6-hour chilling treatment, 24 hours after chilling, and 72 hours after chilling. After continuous chilling, birds were drained 15 minutes before weighing.

Birds treated without continuous chilling were weighed four times--when removed from the line, at the end of the 6-hour chilling period, 24 hours after chilling, and 72 hours after chilling.

Mean percentage loss, based on total gained weight, was calculated in this trial, rather than mean percentage gain.

Trial III

The treatments in Trial III were:

(a) initial pH of the chilling medium (3, 5, 7, 8, 9, or 10) and
(b) proportion of phosphate mixture (none, 2, or 8 ounces per gallon).

The birds were chilled for 6 hours. Either sodium hydroxide (NaOH) or hydrochloric acid (HCl), or both, were added to the chilling medium to obtain the desired pH, as indicated by a pH meter.

Where phosphate was added to the chilling medium, pH was adjusted to the specified level after the addition of phosphate. There were 12 birds per treatment per replicate, 2 replicates (1 a day for 2 days), for a total of 432 birds. Each bird was weighed three times--when removed from the line, at the end of the 6-hour chilling period, and 24 hours after chilling.

Trial IV

The treatments in Trial IV were:

(a) period of time that solution was air-agitated during chilling (none, 1, and 6 hours) and

(b) temperature of chilling solution (32°-34° F. for entire chilling period, or 65° F. for 1 hour, then 32°-34° for remainder of chilling period).

The birds were chilled for 6 hours. The chilling medium was agitated by flowing compressed dried air through perforated plastic tubes in the bottom of the containers. There were 12 birds per treatment per replicate, 4 replicates (2 a day for 2 days), for a total of 288 birds. The chilling medium contained 8 ounces of phosphate mixture per gallon. Each bird was weighed three times--when removed from the line, at the end of the 6-hour chilling period, and 24 hours after chilling.

Moisture Sources Bypassed

In the subsequent descriptions and interpretations of the findings of this study, the relative effects of the treatments, rather than the absolute gains or losses, are usually emphasized. The relative effects are more meaningful, because important sources of moisture which normally affect commercially processed chickens were, of necessity, bypassed. Although the inclusion of these sources of moisture would have more accurately represented total moisture gain in commercial practice, the introduction of another variable would have complicated the analysis and interpretation.

In all trials, the final washer after evisceration but before the chiller, an important source of moisture, was bypassed. Water uptake in this washer, depending on the type and method of operation, may range from 2 to 3 percent (7). The continuous chiller, commonly used in commercial plants, was bypassed in all trials except part of trial II. Percent gain in the various types of continuous chillers may range from 4 to 15 percent (7) depending upon the method of operation.

RESULTS AND DISCUSSION

Weights of Sample Birds

The means and standard deviations of dry eviscerated weights of sample birds for each trial were as follows: Trial I, 2.35 ± 0.37 pounds; trial II, 2.62 ± 0.40 pounds; trial III, 2.44 ± 0.35 pounds; and trial IV, 2.53 ± 0.42 pounds.

Effect of Phosphate

When weighed soon after being chilled for 6 hours in water containing 8 ounces of phosphate mixture per gallon, birds of trial I, gained less than birds chilled in water without added phosphate (table 1). This difference was statistically significant (1% level) according to analysis of variance. When birds were weighed after 24 hours of shipping and holding, the differences in gain between birds chilled with phosphate and birds chilled without phosphate were not significant.

These results agree, in general, with other recent investigations wherein gains by controls, were compared with gains by birds subjected to various proportions of phosphate mixture. Klose and others (6) found that birds in phosphate mixtures of about 6.7 ounces per gallon gained less than controls. May and others (9) determined that at a level of 4 ounces per gallon, gains were greater than in controls; at 8 ounces, they were about the same; and at 10 ounces, they were less than in controls. Mountney and Arganosa (11) reported less gain than in controls after 2 and 8 hours of chilling in 8 ounces of phosphate per gallon; but after 24 hours of soaking, the difference was not significant. Schermerhorn, Adams, and Stadelman (12) found little difference between controls and birds soaked in 5.3 ounces of phosphate per gallon, but found significant lowering of gain at the 16-ounce-per-gallon level. Spencer and Smith (13) found about the same gain at the 10-ounce-per-gallon level as in controls. Mahon (8) reported that, except at 4 ounces and 24 hours, chickens treated with 4, 8, or 16 ounces of phosphate per gallon for periods of 2, 6, and 24 hours gained less weight than controls. Valdecantos and others (17) showed that chickens soaked in a 500-p.p.m. solution of sodium hexametaphosphate for 2 hours immediately after evisceration shrank less, as measured in the birds after storage at 32° F. and 92 percent relative humidity for 14 or more days, than birds that were dry chilled. Both soaked and dry chilled lots were unacceptable.

Although phosphate-treated birds tend to take up less water, greater water retention in these birds may lead to difficulty in conforming to regulations (15). Icepacked poultry may legally absorb, during chilling, up to 12 percent of its dry eviscerated weight, but fryers, at time of consumer packaging, must not show more than an 8 percent gain over their dry eviscerated weight. Thus, if chilling gain is near or at the maximum allowed, phosphate-treated birds may not lose enough during holding and transportation to meet percentage tolerances for consumer packages.

Effect of Chill Time

A Duncan Multiple Range Test (2) and analysis of variance of the data from Trial I (table 1) showed that the birds chilled for 2, 6, 18, and 24 hours gained and retained weight in direct proportion to duration of chill; the increases were significant at the 1-percent level. This substantiates results of other investigations (3, 7, 8).

Effect of Continuous Chilling

In trial II, birds chilled without continuous chilling, regardless of whether or not any of the compounds were added to the chilling medium gained about 4 to 4.5 percent. However, in the continuous chiller, birds gained about 8 to 9 percent, then an additional 3 to 3.5 percent during the subsequent 6-hour treatment. If these birds had not bypassed the final washer, where 2 to 3 percent would probably have been picked up, a total gain of 13 to 15.5 percent would probably have resulted. Considering the methods by which fryers are presently marketed, treatment chilling combined with continuous chilling could lead to an inordinate percent gain. However, modifications in processing procedures, applied to final washing, continuous chilling, and treatment soaking, might reduce percentage gains to meet regulations.

Moisture Loss During Holding

Within 24 hours after chilling, birds that had been chilled by 6-hour treatment alone lost about the same percentage of their gained weight as birds that had been chilled by the combination of continuous chilling and 6-hour treatment (table 2). In the group chilled for only 6 hours, there was no statistically significant difference among treatments. In the combination group, however, the phosphate-treated birds lost significantly less in the first 24 hours. The birds chilled in 8 ounces of phosphate for only 6 hours gained significantly in weight in the period between 24 and 72 hours after chilling. These

birds continued to pick up moisture from melting ice after chilling. All other birds chilled for only 6 hours either maintained their weight or lost relatively little. The birds chilled by the combination of continuous and 6-hour chilling lost additional weight between 24 and 72 hours of storage. In this combination group, the birds treated with 8 ounces of phosphate per gallon lost a significantly lower percentage between 24 and 72 hours after chilling than most other birds within the group; the loss amounted to one-third of that occurring in birds chilled with no compound added to the chilling medium. Soaking birds in 8 ounces of phosphate per gallon for 6 hours after continuous chilling significantly reduced total weight loss during a 72-hour holding period to about one-half to two-thirds of that which occurred when the other 6-hour treatments were used after continuous chilling.

Effect of NaCl

In trial II, 0.112 or 1.120 ounces of NaCl added per gallon of chilling medium had no significant influence on weight gain during chilling.

Effect of pH

Table 3 summarizes the results of trial III. Analysis of variance and the Duncan Multiple Range Test (2) showed that the differences between the mean percentage gain of birds chilled at pH 10 and the gains at every other pH were significant at the 5-percent level, when birds were weighed immediately after chill and after 24 hours' holding. After chill, these differences ranged from 2.8 to 4.9, and after 24 hours' holding, they ranged from 2.5 to 4.5. Thus, a strongly alkaline chilling medium may contribute to inordinate gains. Differences between and among pH 3, 5, 7, 8, and 9 were not statistically significant. Hamm (5) found that the hydration of red meat varied as a function of the pH of the meat itself. He noted a decline in hydration between pH 3 and pH 5, and showed that from pH 5 to pH 10 hydration increased in direct proportion to pH. The pattern in which moisture uptake varied as a function of initial pH of chilling solution was similar for chicken meat (table 3).

From pH 3 through pH 8, the usual tendency for greater moisture retention by phosphate-treated birds, than by birds not treated with phosphate, was evident, but at pH 9 and pH 10 the phosphate-treated birds tended to retain less of the moisture gained. The lack of statistical significance among the data for pH 3 through pH 9 occurred because of unexplained variation among replicates in the lower pH groups. This variation may be assumed to be a function of the concentrations of sodium and chloride ions resulting from the HCl and NaOH which were added to obtain the desired pH.

If the sequence of preparation of the pH solutions had been different, the results would probably have differed considerably from those reported here. This difference would have been particularly evident if the pH of the tap water had been adjusted before, rather than after, the phosphate was added. As Mahon[2] has noted, at a level of 8 ounces per gallon, the phosphate solution exhibits a pH of 8.5, and if 8 ounces is added to either natural tap water or tap water previously adjusted to the extremes of pH 3 or 10, the pH of the final solution would be very near 8.5. Thus, the pH of the phosphate solution is not, in a practical sense, affected by the pH of the tap water used. However, the pH of the solution can be deliberately altered by adding sufficient acid or base after the phosphate. Despite this, if phosphate were present, it would tend to reduce moisture uptake, even at pH 10 (table 3).

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[2] Mahon, John H. Personal Communication, 1962.

Effect of Air Agitation and Temperature

Table 4 is a summary of results of trial IV. No statistically significant difference was found between mean percentage gains as influenced either by the temperatures of the chilling solutions, or the length of time air agitation was applied to the solutions. Thus, temperatures higher than that of slush ice or application of air agitation during chilling in phosphates, within the limits set by practicality and regulations, appeared to have no particular effect on moisture uptake. Thomson and others (14) have shown that prechilling at 70° F. followed by chilling at 32° to 34° was associated with a higher gain than at 32° to 34° for the entire period. The findings of Mickelberry and others (10) may have a bearing on the effect of higher chilling temperatures on moisture uptake; prechilling at higher temperatures would necessarily involve a lower ice-to-water ratio.

Interactions

None of the interactions between treatments concerned with proportion of phosphate mixture and other variables was statistically significant. Thus, the effect of the proportion of phosphate was not conditioned by the influence of the other factors studied in these experiments, and conversely, the effect of other factors was not limited by the effect of proportion of phosphate.

Physical Effects of Phosphates

A bleached appearance and slippery texture of phosphate-treated carcasses, which may affect their acceptability, was evident in these experiments. In addition, the problem of irritation of workers' skin, may require special consideration.

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TABLE 1.--Moisture uptake by fryer chickens as affected by adding phosphates to chilling solution and by duration of chilling[1]

Phosphate added per gallon of water	Mean percentage gain by fryers			
	Chilled 2 hours		Chilled 6 hours	
	After chill	24 hrs. later[2]	After chill	24 hrs. later[2]
	Percent	Percent	Percent	Percent
None	4.0	2.1	5.3	2.6
8 ounces	3.0	1.6	4.3	2.6

Phosphate added per gallon of water	Mean percentage gain by fryers			
	Chilled 18 hours		Chilled 24 hours	
	After chill	24 hrs. later[2]	After chill	24 hrs. later[2]
	Percent	Percent	Percent	Percent
None	7.5	4.9	8.4	5.8
8 ounces	6.2	5.7	6.9	6.0

[1] No final washing or continuous chilling.
[2] Elapsed time after completion of chilling.

TABLE 2.--Moisture loss by fryer chickens as affected by added phosphates, NaCl, and method of chilling

Compound added per gallon in 6-hour treatment chill	Mean percentage loss of fryers					
	Chilled in 6-hour treatment without final washing or continuous chilling			Chilled in continuous chiller followed by 6-hour treatment--no final washing		
	Between chill and 24 hrs. later	Between 24 and 72 hrs.	Between chill and 72 hrs.	Between chill and 24 hrs. later	Between 24 and 72 hrs.	Between chill and 72 hrs.
None.....	[1] 36 a	2 b c	38 c	36 b	12 b	48 d
4 oz. phosphate	28 a	2 b c	30 b	27 a	9 b	36 b
8 oz. phosphate	26 a	[2] 5 a	21 a	24 a	4 a	28 a
0.112 oz. NaCl	31 a	0 b	31 b	37 b	8 a b	45 c d
1.120 oz. NaCl	32 a	5 c	37 c	34 b	9 b	43 c

[1] Means within a column followed by the same letter are not significantly different at the 5% level according to analysis of variance and Duncan Multiple Range Test (2).
[2] Mean percentage gain, not loss.

Table 3.--Moisture uptake by fryer chickens as affected by added phosphates and initial pH of chilling medium[1]

Phosphates added per gallon of water (ounces)	Mean percentage gain in moisture with initial pH of--					
	3		5		7	
	After chill[2]	24 hrs. later[3]	After chill[2]	24 hrs. later[3]	After chill[2]	24 hrs. later[3]
	Percent	Percent	Percent	Percent	Percent	Percent
None	4.2	2.2	3.5	1.8	4.1	2.6
2	4.2	3.2	3.3	2.1	4.7	3.2
8	6.4	4.6	3.5	2.2	3.9	2.6

Phosphates added per gallon of water (ounces)	Mean percentage gain in moisture with initial pH of--					
	8		9		10	
	After chill[2]	24 hrs. later[3]	After chill[2]	24 hrs. later[3]	After chill[2]	24 hrs. later[3]
	Percent	Percent	Percent	Percent	Percent	Percent
None	5.1	3.6	5.7	4.3	9.9	8.9
2	5.8	4.2	7.0	4.9	7.9	6.0
8	4.4	3.3	3.9	2.8	6.0	4.8

[1] No final washing or continuous chilling.
[2] Six-hour treatment chill.
[3] Elapsed time after completion of chilling.

Table 4.--Moisture uptake by fryer chickens as affected by temperature and air agitation of phosphate chilling medium (8 ounces per gallon)[1]

Temperature of chilling medium	Mean percentage gain in moisture with--					
	No air agitation		Air agitation for 1 hour		Air agitation for 6 hours	
	After chill[2]	24 hrs. later[3]	After chill[2]	24 hrs. later[3]	After chill[2]	24 hrs. later[3]
32°-34° F.....	4.5	3.1	4.1	3.5	4.4	3.3
65° F. for 1 hour, then 32°-34°....	4.4	3.4	4.2	3.2	5.1	3.9

[1] No final washing or continuous chilling.
[2] Six-hour treatment chill.
[3] Elapsed time after completion of chilling.